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Personality, Sleep, and Mortality

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ABSTRACT

Personality traits and sleep are associated with health and longevity; however, no investigation has examined whether sleep is a pathway linking personality to mortality risk. Thus, we tested this effect across a 20-year mortality follow-up period in the Midlife Development in the United States (MIDUS) cohort (N = 3,253; *M* age = 47.03 years, *SD* = 12.39, range = 20-75), using proportional hazards in a structural equation modeling (*SEM*) framework. Openness was the only trait predictor of death risk. Daytime sleepiness and short and long sleep duration also emerged as predictors of mortality risk. We found indirect effects for neuroticism, agreeableness, and extraversion on mortality risk through these sleep components. Our findings suggest sleep is a mechanism underlying the personality-mortality effect and has applications for personality-based health interventions.

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Table of Abbreviations

MIDUS = Midlife Development in the United States
SEM = structural equation modeling
HBM = Health Behavior Model of Personality
BMI = body mass index
SAQ = self-administer questionnaire
MIDI = Midlife Development Personality Inventory (Lachman & Weaver, 1997)
NDI = National Death Index
MLR = maximum likelihood robust estimator
HR = hazard ratio
CI = confidence interval
AIC = Akaike Information Criterion
SBC = Schwarz Bayesian (Information) Criterion

Personality, Sleep, and Mortality

Personality characteristics predict all-cause mortality risk (e.g., Friedman et al., 1993; Turiano, Chapman, Gruenewald, & Mroczek, 2015). With ample support for this finding now established, there is growing interest in the mechanisms underlying this association. Accordingly, many studies report that health behaviors, such as smoking and exercise, mediate this effect (e.g., Turiano et al., 2015). However, these behaviors only account for a small portion of the variance in this association. Thus, other health behavior mechanisms need to be examined. One such health behavior, sleep, has been associated with both personality (e.g., Duggan, Friedman, McDevitt, & Mednick, 2014; Gray & Watson, 2002) and longevity (e.g., Kripke, Garfinkel, Wingard, Klauber, & Marler, 2002; Kronholm, Laatikainen, Peltonen, Sippola, & Partonen, 2011), yet no study has investigated whether sleep is a pathway linking personality to mortality risk. Using data from the Midlife Development in the United States (MIDUS) study, we addressed this issue, examining whether sleep duration and quality mediated the personality-mortality association (see Figure 1).

Personality-Mortality

Personality refers to characteristic patterns of cognition, affect, behavior, and motivation that are present across many contexts. The Big Five Theory conceptualizes global personality structure as consisting of five hierarchical dimensions: conscientiousness, agreeableness, neuroticism, openness, and extraversion (see Table 1 for a chart of the Big Five trait and facet structure; Costa & McCrae, 1992; Goldberg, 1992). Among these traits, conscientiousness (i.e., the tendency to be self-disciplined, organized, and industrious) consistently predicts increased longevity, across cultures (e.g., Iwasa et al., 2008; Turiano et al., 2012), age groups (e.g., children: Friedman et al., 1993; Martin, Friedman, & Schwartz; middle-aged adults: Chapman et

al., 2010; Turiano et al., 2015; older adults: Costa et al., 2015; Weiss & Costa, 2005; Wilson, Mendes de Leon, Bienias, Evans, & Bennett, 2004), and follow-up periods (e.g., Friedman et al., 1993; Martin et al., 2007), as confirmed by meta-analyses (Jokela et al., 2013; Kern & Friedman, 2008).

However, the findings involving neuroticism (i.e., the tendency to be emotionally reactive and to experience depression, anxiety, and anger) are not as consistent. Some studies report no effect (e.g., Maier & Smith, 1999; Turiano et al., 2015), yet others report inverse (Ploubidis & Grundy, 2009; Weiss & Costa, 2005) and positive effects (e.g., Friedman et al., 1993; Martin et al., 2007) for neuroticism on mortality risk.

One aspect of low agreeableness (i.e., the tendency to be cooperative vs. aggressive), hostility, has been consistently positively associated with mortality as confirmed by meta-analyses (Miller, Smith, Turner, Guijarro, & Hallet, 1996). Among studies employing comprehensive measures of agreeableness, many studies report no association (e.g., Christensen et al., 2002; Turiano et al., 2015). However, higher agreeableness has both predicted an increased risk of dying (Friedman et al., 1993; Martin et al., 2007) and protected against death risk (Costa & Weiss, 2005; Costa et al., 2014). Overall, the evidence connecting agreeableness to mortality risk is weaker, with mixed findings.

Many studies report no association between openness (i.e., the tendency to be intellectually curious, imaginative, and have liberal values) and mortality risk (e.g., Maier & Smith, 1999; Turiano et al., 2015). However, there is emerging evidence that higher openness is protective against mortality risk at the trait (e.g., Iwasa et al., 2008; Jackson et al., 2015) and facet level (e.g., Jonassaint et al., 2007; Turiano et al., 2012), consistent with a meta-analysis (Ferguson & Bibby, 2011).

Most studies report no association between extraversion (i.e., the tendency to be friendly, assertive, and to experience positive emotions) and longevity (e.g., Korten et al., 1999; Jokela et al., 2013). However, higher extraversion has both protected against mortality risk (Iwasa et al., 2008; Lockenhoff, Zonderman, Ferrucci, & Costa, 2008) and predicted increased death risk (Ploubidis & Grundy, 2009). Thus, the evidence for an extraversion-mortality association is also mixed.

Mediators of the Personality-Mortality Association

Given findings linking personality traits to mortality risk, there is interest in exploring mechanisms underlying this effect. The Health Behavior Model (HBM) of personality (Smith, 2006; see Figure 1) postulates that aspects of personality lead one to engage in behaviors (e.g., smoking, alcohol use) that impact health and longevity over time. Accordingly, there is a body of literature examining whether health behaviors explain the personality-longevity association.

Earlier studies focusing on the HBM were limited as no formal mediational tests were employed (for a review, see Turiano et al., 2015). Rather, these studies relied on entering health behaviors as covariates into models testing the personality-mortality association, often finding that adjusting for health behaviors partially or fully attenuated the effect of personality on longevity. When this occurred, it was interpreted as indicating that health behaviors may account for a portion of the variance in the personality-mortality association.

Indeed, these studies found support for such an effect. For example, adjusting for smoking, alcohol use, and body mass index (BMI) attenuated the effect of neuroticism on mortality risk by 6.1% (Wilson et al., 2004); 12.1% (Nabi et al., 2008); and 20% (Mroczek et al., 2009). Thus, these findings indicate that the personality-mortality effect may be partially explained by health behaviors, but are limited as no formal mediational tests were employed.

This limitation was primarily methodological as traditional mediational analyses allow for either continuous or discrete outcome variables, but not outcome variables, such as mortality risk, that are both continuous (i.e., survival time) and discrete (i.e., dead or alive). However, recent methodological advances have extended the use of proportional hazards modeling in structural equation modeling (*SEM*) frameworks, allowing for mediational tests with outcomes that are both continuous and discrete (Asparouhov, Masyn, & Muthén, 2006; Muthén & Masyn, 2005). This modeling technique allows for the predictive effect of personality on behavioral mediators to be calculated, as well as the effect of the behavioral mediators on mortality risk. Importantly, this technique allows for estimating the statistical significance of these indirect effects—a statistical requirement for confirming mediation.

A recent study employing this technique used data from the MIDUS cohort and examined conscientiousness, finding that multiple health behaviors explained 42% of the variance in the conscientiousness-mortality association (Turiano et al., 2015). Using proportional hazards modeling in an *SEM* framework, the predictive effects of conscientiousness on each of these mediators (i.e., alcohol use, smoking, waist circumference) and the effect of each of these mediators on longevity was calculated and the indirect effects were significant. The authors found that individuals scoring lower on conscientiousness were more likely to be heavy alcohol users, a current or former smoker, and were more likely to have a larger waist circumference, which increased the hazard of dying over the 14-year follow-up.

The authors of this study reviewed the literature, concluding that health behaviors, such as tobacco use and physical activity, generally accounted for 0% to 26% of the variance in the personality-mortality association (Turiano et al., 2015). Given that a large portion of the personality-mortality variance remains unexplained after incorporating measures of these health

behaviors, other mechanisms need to be explored. One such mechanism, sleep, is a robust predictor of health outcomes (e.g., metabolic syndrome: Hall et al., 2008; obesity: Buxton et al., 2010; mortality risk: Hublin et al., 2011), yet has been overlooked in the personality-health literature. Addressing this oversight remains important: unlike many behavioral mechanisms (e.g., alcohol consumption, smoking, substance use), sleep is a universal health behavior that is amenable to treatment (Espie, 2002).

Personality-Sleep

Three components of sleep are jointly important for health: sleep duration (i.e., number of minutes slept per night), sleep quality (i.e., ease of falling asleep and staying asleep and feeling rested upon waking), and sleep timing (i.e., consistently maintaining the same sleep schedule) (Czeisler, 2015). Behaviors that interfere with sleep (e.g., inconsistent sleep schedules; increased anxious arousal at bedtime) are associated with insufficient and poorer quality sleep (Brown, Buboltz, & Soper, 2002; Gellis, Park, Stotsky, & Taylor, 2014). Given that aspects of personality (e.g., lower conscientiousness, higher neuroticism) encompass such behaviors, it is not surprising that personality traits have been associated with sleep (e.g., Duggan et al., 2014; Gray & Watson, 2002). In this study, we focused on two aspects of sleep, duration and quality, as these are the only sleep components for which data are available from MIDUS.

Among the big five traits, neuroticism and conscientiousness consistently predict these sleep components. Specifically, neuroticism is associated with sleep deprivation (e.g., greater sleep deficiency: Hinstanen et al., 2014; shorter duration: Vincent, Cox, & Clara, 2009; but see also Gray & Watson, 2002) and poorer sleep quality across diverse samples (e.g., college students: Duggan et al., 2014; Gray & Watson, 2002; community adults: Hinstanen et al., 2014; cross-culturally: Kim et al., 2014). Although some studies reported no effect for

conscientiousness on sleep quality (e.g., Duggan et al., 2014; Hinstanen et al., 2014), it is inversely associated with sleep quality (e.g., Gray & Watson, 2002; Moroz & Williams, 2009) and duration (e.g., Grano et al., 2007; but see also Gray & Watson, 2002) across most studies.

However, findings for the effect of other traits are less robust. Although agreeableness has been positively associated with sleep duration (Hinstanen et al., 2014), it has not been associated with sleep quality (e.g., Duggan et al., 2014; Gray & Watson, 2002). Additionally, to our knowledge, no studies have linked extraversion or openness to sleep duration or quality (e.g., Duggan et al., 2014; Gray & Watson, 2002).

Sleep-Mortality

Although sleep duration has been positively associated with mortality risk in a linear manner (e.g., longer duration: Chen, Su, & Chou, 2013; Kronholm, Laatikainen, Peltonen, Sippola, & Partonen, 2001; e.g., shorter duration: Kronholm et al., 2001), evidence for a U-shaped effect (i.e., short and long sleep duration predicting increased mortality risk) is more robust and emerges across age groups (e.g., childhood: Duggan, Reynolds, Kern, & Friedman, 2014; adulthood: Kripke, Garfinkel, Wingard, Klauber, & Marler, 2002; Kronholm et al., 2001; older adulthood: Hublin, Partinen, Koskenvuo, & Kaprio, 2007; Xiao, Keadle, Hollenbeck, & Matthews, 2014) and cultures (e.g., Kojima et al., 2000), consistent with meta-analyses (Cappuccio, D'Elia, Strazzullo, & Miller, 2009; da Silva et al., 2016). Whereas short sleep duration is thought to relate to mortality risk due to its association with risk factors (e.g., reduced leptin; Taheri, Lin, Austin, Young, & Migniet, 2004) for conditions such as obesity, long sleep duration is generally considered a marker for undiagnosed disease (e.g., Cappuccio, Cooper, D'elia, Strazzullo, & Miller, 2011).

Like sleep duration, poorer sleep quality has also been associated with reduced life expectancy across diverse samples (e.g., cross-culturally: Kojima et al., 2000; community adults: e.g., Ensrud et al., 2012; Rockwood, Davis, Merry, MacKnight, & McDowell, 2001). Despite these consistent findings, some studies failed to replicate the sleep quality-mortality effect (e.g., Chen et al., 2013; Kripke et al., 2002).

Statement of the Problem

The purpose of this study was to extend the personality-mortality literature. Several studies suggest that lower conscientiousness is related to increased mortality risk (e.g., Christensen et al., 2002; Turiano et al., 2012) and that health behaviors, such as alcohol use, smoking, and physical activity, underlie this association (e.g., Turiano et al., 2015). However, these health behaviors only account for a small portion of the variance in the pathway linking personality to longevity. Thus, other health behavior mechanisms need to be explored.

One such health behavior, sleep, has been associated with both personality (e.g., Duggan et al., 2014) and longevity (e.g., Kojima et al., 2000). Specifically, higher neuroticism and lower conscientiousness have been associated with shorter sleep duration and poorer sleep quality (e.g., Duggan et al., 2014; Hinstansen et al., 2014). Moreover, short and long sleep duration (e.g., Duggan et al. 2014; Kripke et al., 2002) and poorer sleep quality (e.g., Kojima et al., 2000; Chen et al., 2013) have been associated with reduced life expectancy. However, no study has examined whether these sleep components significantly mediate the personality-mortality association. Thus, we tested this effect in a large national sample of adults, expanding the HBM of personality by uniting segmented areas of research linking personality to sleep (e.g., Duggan et al., 2014; Gray & Watson, 2002) and mortality risk (e.g., Friedman et al., 1993; Turiano et al., 2011 (e.g., Gray & Watson, 2002), and sleep to mortality risk (e.g., Duggan et al., 2014; Kojima

et al., 2000) to test the full HBM. Notably, our tests of the HBM also added to the literature aimed at developing personality-based health interventions by exploring pathways linking personality traits to premature death.

Research Questions

Our tests in research questions 1-4 (i.e., the direct effect of sleep components and personality traits on mortality risk; effect of adjusting for sleep components on the personality-mortality association as preliminary evidence of mediation) followed the method of Baron and Kenny (1986) for testing mediation (i.e., historically the preliminary requirement of direct effects of the independent [X] and mediator variables [M] on the dependent variable [Y]). However, because X can be related to Y via the indirect effect of M without a direct effect of X on Y (Hayes, 2009), we tested whether sleep components mediated the personality-mortality effect (research question 5) regardless of whether a direct effect of personality on mortality risk emerged.

Question 1. Does sleep duration predict mortality risk in a linear and/or curvilinear manner? We predicted that sleep duration would be associated with mortality risk in a U-shaped manner, consistent with previous findings (e.g., Duggan et al., 2014; Kripke et al., 2002).

Question 2. Which aspects of sleep quality are most predictive of mortality risk? We tested the effect of our 4-item sleep quality measure on mortality risk. Then we broke our measure into separate measures of sleep problems (items 1-3) and daytime dysfunction (item 4), and examined the effect of these sleep components on mortality risk, separately and together. Our tests of sleep quality were exploratory: we made no predictions about which aspects of sleep quality were most related to mortality risk.

Questions 3. Do the big five traits predict mortality risk across 20 years? We predicted that higher neuroticism and lower conscientiousness would be associated with increased mortality risk. However, we made no predictions for the other traits, given inconsistent findings between mortality risk and openness, extraversion, and agreeableness (e.g., Friedman et al., 1993; Turiano et al., 2015).

Question 4. Does adjusting for sleep variables reduce the effects of personality on mortality risk? We adjusted our models for any sleep components (i.e., the linear and quadratic effect of sleep duration; full sleep quality measure; 3-item sleep problems; daytime dysfunction) that emerged as predictors of mortality risk in our previous models. We expected that adjusting for sleep components would attenuate the strength and possibly significance of the personality-mortality association, providing preliminary evidence of mediation.

Question 5. Do sleep variables mediate the personality-mortality association? Regardless of whether there was a direct effect of personality on mortality risk, or whether including sleep components in the models changed the strength or significance of the personality-mortality association, we tested the mediating effect of any sleep variables that emerged as predictors of mortality risk in our previous models. We expected that sleep components would mediate the neuroticism-mortality and conscientiousness-mortality associations via the calculated significance of indirect effects. However, we made no predictions for the mediating effect of sleep components on the other traits, given inconsistent findings for the effects of agreeableness, openness, and extraversion on sleep duration (e.g., Granö et al., 2007; Gray & Watson, 2002), sleep quality (e.g., Duggan et al., 2014; Gray & Watson, 2002), and mortality risk (e.g., Friedman et al., 1993; Turiano et al., 2015).

Method

Sample

Data came from the National Survey of Midlife Development in the United States (MIDUS), a longitudinal multidisciplinary study of psychosocial development and health in a national sample of adults (for review, see Brim, Ryff, & Kessler). MIDUS includes three waves of data: MIDUS 1, collected in 1995-1996; MIDUS 2, collected in 2004-2006; and MIDUS 3, collected in 2013-2016. We used data from MIDUS 1 and MIDUS 2, enabling us to utilize the largest amount of mortality deaths, as well as the temporal ordering needed to establish mediation.

The MIDUS 1 sample included 7,108 non-institutionalized English speaking adults in the coterminous United States, aged 25 to 74. The sample was recruited using random digit dialing techniques, oversampling for men and older individuals to ensure adequate representation of these populations as they tend to be less likely to participate in research studies (e.g., Murthy, Krumholz, & Gross, 2004). Participants completed a telephone interview and a self-administered questionnaire (SAQ). MIDUS 1 participants were invited to participate in MIDUS 2. Of the 7,108 participants, 4,963 (75% adjusted for mortality) completed a phone interview at MIDUS 2 (see Table 1 for an attrition diagram). Of those 4,963 participants who completed the phone interview, 4,032 (81%) completed an SAQ. Of these 4,032 participants, 3,253 provided complete MIDUS 1 and MIDUS 2 data used in our study and were included in our sample (see Figure 2).

Compared to participants included in our sample, participants who dropped out or had missing data were more likely to be male ($\chi^2 = 12.46$, $p < .001$); minority status ($\chi^2 = 52.35$, $p < .001$); single ($\chi^2 = 62.22$, $p < .001$); less educated ($t = 12.34$, $p < .001$); lower on self-rated

health ($t = 10.25$, $p < .001$); lower on conscientiousness ($t = 5.56$, $p < .001$); higher on agreeableness ($t = -3.63$, $p < .001$); higher on extraversion ($t = -2.56$, $p < .05$); living with a child aged two years or younger ($\chi^2 = 12.73$, $p < .001$); and more likely to have poorer sleep quality ($t = -2.71$, $p < .01$); higher daytime dysfunction ($t = -2.33$, $p < .05$); more sleep problems ($t = -2.47$, $p < .05$); less likely to be retired ($\chi^2 = 39.66$, $p < .001$) and work night shifts ($t = 5.40$, $p < .001$). There were no differences in age, neuroticism, openness, waist circumference, or sleep duration.

Measures

Covariates. We adjusted our models for the following covariates (see Appendix) measured at MIDUS 1: gender (0 = *female*; 1 = *male*), race (0 = *Caucasian*; 1 = *minority*), age, relationship status (0 = *married or living with a partner*, 1 = *not married or living with a partner*), level of education (1 = *no school/some grade school*; 12 = *Ph.D., ED.D., MD, DDS, LLB, LLD, JD, or other professional degree*), and self-rated health (1 = *poor*, 5 = *excellent*). We also adjusted for retirement status (0 = *not retired*, 1 = *retired*), shiftwork (frequency of night shifts: 0 = *not applicable* 1 = *less than once per month*; 2 = 1-3 *per week*; 3 = 1 *per week*; 4 = 2-3 *per month*; 5 = *4 times per week*), living with a child under the age of two years (0 = *not living a child*; 1 = *living with a child*), and waist circumference measured at MIDUS 2. We adjusted for these covariates because each has been associated with personality traits (gender: Costa, Terracciano, & McCrae, 2001; education: Poropat, 2009; age: Roberts & DelVecchio, 2000; relationship status: Solomon & Jackson, 2014; obesity: Sutin, Ferrucci, Zonderman, & Terracciano, 2011), sleep (living with a child aged two years or younger: Gay, Lee, & Lee, 2004; race: Mezick et al., 2008; shiftwork: Sack et al., 2007; retirement: Vahtera et al., 2009), or mortality risk (self-rated health: Idler & Benyamini, 1997).

Personality. The Midlife Development Personality Inventory (*MIDI*; Lachman & Weaver, 1997) includes 25 adjectives measuring the big five personality dimensions. Participants rated how much each adjective described them, using a scale ranging from 1 (*not at all*) to 4 (*a lot*). The adjectives included: friendly, lively, active, talkative (extraversion; α = .78); moody, worrying, nervous, calm (reverse coded) (neuroticism; α = .75); creative, imaginative, intelligent, curious, broad-minded, sophisticated, adventurous (openness; α = .77); organized, responsible, hardworking, careless (reverse coded) (conscientiousness; α = .60); and helpful, warm, caring, softhearted, sympathetic (agreeableness; α = .82). The *MIDI* (Lachman & Weaver, 1997) was constructed from a pool of adjectives taken from existing personality inventories. The adjectives selected from the pool accounted for 90% of the variance from scores from the item pool. The *MIDI* (Lachman & Weaver, 1997) correlates strongly with NEO personality measures and has good construct validity (Lachman & Weaver, 1997; Mroczek & Kolarz, 1998). Scores for each trait were calculated by averaging the item responses. Higher scores represented higher standing on that trait. We utilized personality data from MIDUS 1.

Sleep Duration. Sleep duration was assessed at MIDUS 2 using self-reported weekday sleep duration (i.e., "How much sleep do you usually get at night [or in your main sleep period] on weekdays or workdays? Hours? Minutes?") and weekend sleep duration (i.e., "How much sleep do you get at night [or in your main sleep period] on weekends or your non-workdays? Hour? Minutes?"). Responses to the number of hours slept were recoded into minutes, then added to the number of minutes slept, yielding scores for weekend and weekday sleep duration in minutes. Following the method of Kong et al. (2011), these scores were averaged to yield a score for total sleep duration, using the formula: ([(5 x weekday duration) + (2 x weekend duration)]/7). Higher scores represented longer sleep duration.

Sleep Quality. Sleep quality (α = .79) was assessed at MIDUS 2 using a four-item self-report measuring trouble falling asleep, staying asleep, waking too early, and feeling unrested during the day. Participants rated how often they experienced these problems using a scale ranging from 1 (*never*) to 4 (*often*). Scores were calculated by averaging the responses across these items (α = .80). Lower scores represented more optimal sleep quality. We also separated this measure into separate constructs (i.e., sleep problems: items 1-3; α = .80; daytime impairment: item 4) and tested our effects using these components.

Vital Status. There were 1,299 deaths in the MIDUS cohort by the censor date, October 31, 2015. Mortality data were obtained using several methods. First, 569 deaths were confirmed from National Death Index (NDI) reports obtained from 2006 to 2009. Second, 153 deaths were confirmed during the closeout phases of MIDUS 2 and 483 deaths confirmed during the closeout phases of MIDUS 3. Third, 94 deaths were confirmed as normal longitudinal sample maintenance was conducted. Only the month and year of death were recorded for the purposes of confidentiality. Thus, the 15th day of each months was assigned as the day of death for all decedents.

We utilized mortality data based on 3,253 participants who provided data on the independent variables. Thus, we are unable to analyze mortality data on 540 deceased individuals because they died before the sleep variables used in the current study were measured in 2005-06. Out of these 3,253 participants, 348 (10.70%) were deceased. Survival time for deceased participants was the interval between when the SAQ data were received by the study team at MIDUS 1 and the date of their death. For participants who are still alive (censored observations), the survival time was the interval between MIDUS 1 and the censored date

(October 15, 2015). The mean survival time was years 14.69 years (*SD* = 2.88; range = 8.98-20.15).

Data Analysis

First, we tested continuous variables for normality by analyzing skewness and kurtosis. Next, we examined the intercorrelations between the independent variables.

To examine Research Questions 1-4 (i.e., the effect of sleep duration, sleep quality, and personality on mortality risk; whether adjusting for sleep components changes the strength or significance of traits on death risk), we conducted a series of proportional hazards models (i.e., Cox models). We used proportional hazards modeling because this technique accounts for continuous survival times, varying ages at entry in the study, and discrete outcomes (i.e., dead vs. alive) (Cox, 1992). Cox models yield an estimate of how much of a standard deviation increase or decrease in a predictor variable predicts the likelihood of dying over a certain time interval. All predictor variables were converted into standard deviation units for ease of interpretation. In addition, we set our alpha level to .05.

We also tested proportional hazards assumptions to ensure that the effects of each predictor were proportional over time (i.e., the strength and statistical significance of the effect was the same across all time points during the 20-year mortality follow-up). First, we mean centered survival time and each continuous predictor, created an interaction term between survival time and each covariate, and included it in the Cox proportional Hazards Model. If an interaction term emerged significant, it meant there was a violation of proportionality; however, including the interaction term corrects for this violation. We also investigated martingale residuals which provides a test of proportionality for each variable based on the empirical score process. Briefly, the empirical score process contrasts the observed empirical score process with

simulated empirical score processes that meet proportional hazards assumptions. Marked deviation between these two indices indicates violations of proportionality.

Research Question 1. Using a series of Cox models, we tested the linear and curvilinear effect of sleep duration. Model 1 included MIDUS 1 covariates (i.e., age, gender, race, self-rated health, education); personality traits; MIDUS 2 covariates (i.e., shiftwork, waist circumference, living with a child under the age of two years, retirement status); and the linear effect of sleep duration. Models 2 and 3 included the quadratic and cubic effect of sleep duration, respectively.

Research Question 2. Using a series of Cox models, we first tested the effect of our full sleep quality measure and then separated sleep quality into separate components (i.e., sleep problems and daytime dysfunction), testing the effect of each component separately and together. Model 1 included MIDUS 1 covariates; personality traits; MIDUS 2 covariates; and the full sleep quality measure. Model 2 included the 3-item sleep problem measure. Model 3 included daytime dysfunction. Model 4 included sleep problems and daytime dysfunction.

Research Question 3. We tested the effect of personality traits on mortality risk using a series of Cox models. Model 1 included MIDUS 1 covariates. Model 2 included personality traits.

Research Question 4. Using a series of Cox models, we tested whether adjusting for sleep variables that emerged as significant predictors of death risk in our previous models changed the strength or significance of the personality-mortality effect. Model 1 included MIDUS 1 covariates; personality traits; and MIDUS 2 covariates. Model 2 included sleep predictors of mortality risk.

Research Question 5. To formally test mediation, we utilized proportional hazards modeling through an *SEM* framework to estimate the direct and indirect effects on survival time

(Asparoouhov et al., 2006). The maximum likelihood robust estimator (MLR) and Monte Carlo integration enables the program to calculate indirect effects like the Sobel method. A *product-of-coefficients* approach computes the ratio of the path from the predictor to the mediator and the path from the mediator to the outcome to its standard error. This technique provides standard errors, confidence intervals, and significance tests. The significance tests enabled us to determine whether there was significant mediation via the significance of an indirect effect. We calculated the indirect effect through any significant sleep predictors of mortality risk and a joint indirect effect through these sleep predictors.

Results

Table 2 provides descriptive statistics for our sample, stratified by survival status. Relative to those who survived, deceased individuals were more likely to be older in age (t = -22.00, $p < .001$); male ($\chi^2 = 14.75$, $p < .001$); less educated ($t = 6.08$, $p < .001$); single ($\chi^2 = 8.98$, $p < .01$); lower on self-rated health ($t = 7.64$, $p < .001$); lower on conscientiousness ($t = 2.50$, $p < .05$); retired ($\chi^2 = 309.75$, $p < .001$); living without a child aged two years or younger ($\chi^2 = 3.84$, $p < .05$); more likely to have a larger waist circumference ($t = -6.08$, $p < .001$); poorer sleep quality ($t = -2.66$, $p < .01$); more sleep problems ($t = -2.72$, $p < .01$); and work fewer night shifts ($t = 11.64$, $p < .001$). There were no differences in race; agreeableness; neuroticism; openness; extraversion; sleep duration; and daytime dysfunction.

As seen in Table 2, values of skewness and kurtosis were within appropriate ranges for continuous variables. However, because weekday and weekend sleep duration were not normally distributed, we winsorized these variables by replacing six outlier data points with the 99th percentile value (i.e., 600 minutes) before averaging weekday and weekend duration together to yield a score for total sleep duration. This normalized the distribution for these

variables. Additionally, we deleted weekday sleep duration data for 34 participants who reported implausible durations (i.e., seven minutes per night).

As seen in Table 3, there were modest positive correlations between our sleep mediators. Specifically, sleep duration was related to the full sleep quality measure ($r = 0.35$; $p < .001$) and each component of sleep quality, when separated into different constructs (daytime dysfunction: $r = 0.22$; $p < .001$; sleep problems: $r = 0.35$; $p < .001$).

Prior to testing the direct effects of personality and sleep, we ensured that all variables met the proportional hazards assumption, using Martingale residuals and by testing the significance of the interaction term between survival time and each continuous variable in Cox models. There were no violations of proportionality.

Research Question 1. Table 4 depicts tests of sleep duration on mortality risk. Model 1 revealed that older age, female gender, lower education, not living with a partner, lower self-rated health, higher openness, being retired, and having a larger waist circumference predicted an increased hazard of dying, but the linear effect of sleep duration was not significant. However, as seen in Model 2, the quadratic effect was significant: each standard deviation increase or decrease in sleep duration was associated with a 10% increased risk of dying over 20 years. However, there was no effect for cubic sleep duration (see Model 3). Figure 3 depicts a graph of the effect of quadratic sleep duration: the effect is significant at two standard deviations below, and one and two standard deviations above, the mean.

Research Question 2. Table 5 depicts the effect of sleep quality. Testing the full measure in Model 1 indicated that older age, female gender, lower education, not living with a partner, lower self-rated health, higher openness, being retired, and having a larger waist circumference were associated with increased death risk; however, there was no effect for sleep

quality. Breaking our measure into separate components (i.e., sleep problems; daytime dysfunction) and testing each separately (Models 2 and 3) and together (Model 4), revealed that daytime dysfunction, but not sleep problems, positively predicted death risk.

Research Question 3. Table 6 depicts the effect of personality traits. Model 1 indicated that older age, female gender, lower education, not being married or living with a partner, and lower self-rated health were predictive of increased mortality risk. Adjusting for personality traits in Model 2 revealed that each standard deviation increase in openness was associated with an 18% increased risk of death over the 20-year follow-up. No other significant direct effects were found for the other personality traits.

Research Question 4. Because short and long sleep duration and daytime dysfunction emerged as predictors of death risk, we examined whether adjusting for these sleep components changed the strength or significance of the personality-mortality effect, as seen in Table 6. Model 3 indicated that older age, female gender, lower education, not being married or living with a partner, lower self-rated health, higher openness, being retired, and having a larger waist circumference positively predicted mortality risk. However, adjusting for sleep components did not change the openness-mortality effect (nor the effect of any other trait), as seen in Model 4.

Research Question 5. Nevertheless, we proceeded to estimate the direct, indirect, and total effect of all five personality traits on mortality risk via daytime dysfunction and quadratic sleep duration, using proportional hazards in an *SEM* framework. All models were adjusted for age, gender, race, education, self-rated health, living with a partner, living with a child aged two years or younger, shiftwork, retirement status, and waist circumference. We found a positive direct effect for openness on mortality risk in all models. Additionally, higher neuroticism was associated with short and long sleep duration (path a*f), which increased the hazard of dying

across 20 years (see Figure 3). Higher neuroticism (path a*f) and agreeableness (path b*f) and lower extraversion (path c*f) predicted higher daytime dysfunction, which was associated with death risk (see Figure 4). Higher neuroticism (sum of paths [a1*f1], [a2*f2]) and agreeableness (sum of paths [b1*f1], [b2, f2]) predicted death risk via the joint indirect effect of both sleep components (see Figure 5).

Supplementary Analyses

We also examined these effects, stratifying our sample by gender and body mass index (BMI).[1] As seen in Table 7, for males, higher neuroticism (HR: 1.04; 95% CI: 0.01, 0.07) and agreeableness (HR: 1.02; 95% CI: 0.00, 0.04), and lower extraversion (HR: 0.98; 95% CI: -0.04, -0.00), were related to increased mortality risk via the indirect effect of higher daytime dysfunction and the joint indirect effect of dysfunction and quadratic duration. In contrast, for females, higher neuroticism (HR: 1.02; 95% CI: 0.00, 0.03) was related to death risk through the indirect effect quadratic sleep duration. Thus, personality was related to sleep primarily through daytime dysfunction for males and through quadratic duration for females.

Among obese individuals[2], neuroticism (HR: 1.05; 95% CI: 0.00, 0.10) and agreeableness (HR: 1.06; 95% CI: 0.00, 0.08) positively predicted mortality risk via the indirect effect of higher daytime dysfunction and the joint indirect effect of both sleep components (neuroticism: HR: 1.07; 95% CI: 0.01, 0.13; agreeableness: HR: 1.05; 95% CI: 0.01, 0.10). However, personality was essentially unrelated to mortality risk through either sleep component when tested individually among non-obese individuals. Thus, we draw caution to interpreting the significant

[1] We also calculated the discrepancy between weekday and weekend sleep duration (M = 37.97 minutes; SD = 50.97; skew: 1.42; kurtosis: 1.63). We tested whether sleep discrepancy predicted mortality risk net of personality traits and found no effect (HR: 1.03; 95% CI: 0.92, 1.16).
[2] We also tested these effects using cut points for larger versus small waist circumference but the results were not appreciably different.

joint indirect effect for neuroticism through both sleep components for this group [HR: 1.04; 95% CI: 0.00, 0.02]. In sum, personality was related to mortality risk primarily through daytime dysfunction among obese individuals.

Discussion

We extended the personality-mortality literature by examining a novel behavioral mediator: sleep. First, we replicated findings linking short and long sleep duration (e.g., Cappuccio et al., 2009; Kripke et al., 2002) and daytime dysfunction (e.g., Ensrud et al., 2012; Rockwood et al., 2001) positively to mortality risk. However, contrary to our expectations and previous findings (e.g., Friedman et al., 1993; Hagger-Johnson et al., 2012), higher openness emerged as the only trait predictor of increased death risk. Additionally, we found indirect effects for higher neuroticism and agreeableness, and lower extraversion, through sleep components.

Many explanations for the sleep-mortality effect exist. Short sleep duration is associated with factors (e.g., inflammation: Patel et al., 2009) that increase the risk of developing conditions such as cardiovascular disease and cancer. However, long sleep duration is often considered a marker for deteriorating health (Cappuccio et al., 2011). Finally, daytime sleepiness is associated with conditions that increase the risk of dying (e.g., cardiovascular disease: Newman et al., 2000).

Our positive direct effect for openness on mortality risk was unexpected: higher openness is generally protective of health (e.g., Iwasa et al., 2008; Turiano et al., 2012). Though the evidence connecting openness to mental health is weak or nonexistent, such associations may have been overlooked because psychopathology (e.g., internalizing symptoms; schizotypal personality features) may be positively related to the creativity aspect of trait openness, but

negatively related to the intellect aspect of openness (see DeYoung, 2014 for a review). Thus, poorer mental health may explain why higher openness predicted reduced life expectancy. Additionally, because prior personality-mortality investigations of the MIDUS cohort (Chapman et al., 2010; Turiano et al., 2015) found no effects for openness, this trait may represent a late onset risk factor for poor health outcomes as the current study used an older sample than previously published reports.

Other novel results included our indirect effects of personality on mortality risk. First, consistent with findings linking neuroticism to sleep (e.g., duration: Vincent, Cox, & Clara, 2009; quality: Duggan et al., 2014), individuals higher on neuroticism reported greater daytime sleepiness and shorter and longer sleep durations, which, increased the hazard of dying across 20 years. These individuals may have difficulty regulating emotions, causing increased anxious arousal that interferes with falling asleep, staying asleep, and, ultimately, feeling rested during the day (Duggan et al., 2014; Gellis et al., 2014). Alternatively, depression may account for this finding: insomnia and hypersomnia are symptoms of depression (American Psychiatric Association) and depression is associated with both higher neuroticism (e.g., Kendler, Kuhn, & Prescott, 2004) and increased death risk (e.g., Schulz, Beach, Martire, Ariyo, & Kop, 2000). Additionally, the positive connection between physical activity and extraversion (Rhodes & Smith, 2006) may account for our indirect effects for low extraversion, given that sedentary lifestyles can impair sleep (Morgan, 2003). Lastly, perhaps maladaptive aspects of higher agreeableness (e.g., preoccupation with interpersonal relationships; difficulty being assertive [e.g., difficulty telling others “no”]; Samual & Gore, 2012) contribute to abnormal sleep durations and daytime sleepiness, thereby adversely affecting health and longevity over time.

Additionally, given gender differences in sleep patterns (e.g., Zhang & Wing, 2006), we tested whether our indirect effects differed for males and females. Our results suggested that personality was related to death risk primarily through daytime dysfunction in males and quadratic sleep duration in females. We are unable to discern why this pattern of effects emerged, given findings of no gender differences in the sleep-mortality effect (e.g., duration: Cappuccio et al, 2010; daytime dysfunction: Rockwood et al., 2001) and an investigation linking daytime sleepiness positively to death risk in females, but not males (Newman et al., 2000). Thus, further research is needed to determine why abnormal sleep durations and daytime sleepiness would be especially physiologically detrimental to females and males, respectively.

Similarly, given the higher prevalence of sleep disturbances among obese individuals (Dixon, Dixon, Anderson, Schachter, & O'Brien, 2007; Vgontzas et al., 1998), we tested whether these effects differed in obese vs. non-obese individuals. Our results indicated that personality was related to mortality risk primarily through daytime dysfunction for obese individuals, but not non-obese individuals, which may be accounted for by the higher rate of daytime sleepiness among obese individuals (e.g., Dixon et al., 2007; Vgontzas et al., 1998).

Overall, our results are consistent with findings linking personality to sleep (e.g., Duggan et al., 2014; Gray & Watson, 2002) and sleep to mortality risk (e.g., Duggan et al., 2014; Kronholm et al., 2001) and included several strengths. First, we utilized a parsimonious modeling technique to formally test mediation using proportional hazards, giving us empirical evidence of a novel behavioral pathway connecting personality to longevity: sleep. Additionally, our mediation tests of quadratic sleep duration advanced the personality-health literature methodologically. Traditionally, researchers assume linear relations between independent, mediator, and dependent variables when testing mediation. However, many variables are related

in a nonlinear manner, including sleep duration and mortality risk (e.g., Duggan et al., 2014; Kripke et al., 2002). Thus, testing mediation of quadratic sleep duration was theoretically sound, allowing us to detect an effect that would otherwise be overlooked. These mediation tests also represented a more statistically robust approach than alternative methods, such as testing our effects in subgroups (i.e., short, average, long duration), which masks important individual differences and inflates the risk of obtaining spurious results (Hayes & Preacher, 2010). Finally, testing quadratic sleep duration allowed us to connect personality to sleep duration (e.g., Gray & Watson, 2002), an effect that rarely emerges in the personality-sleep literature, perhaps because curvilinear effects have been overlooked.

In addition, our results have implications for personality-based health interventions, offering insights into what treatments would be effective for whom. Specifically, our findings indicate that reducing daytime sleepiness and normalizing sleep duration might improve longevity among those higher on neuroticism and agreeableness. For individuals lower on extraversion, daytime sleepiness might be an effective treatment target. Alternatively, changing these aspects of personality could improve sleep, enhancing health and longevity. These findings also highlight the utility of using personality assessment in personalized medicine to identify those at risk for health problems, whether it be for sleep problems or poor health outcomes.

Despite these practical applications, our study included some limitations. First, our sample was predominately Caucasian and highly educated, potentially limiting generalizability. Nevertheless, our investigation is the first to test whether sleep components explain the personality-mortality association in a large national sample. Moreover, we are not aware of any research suggesting that our findings would differ in more diverse samples (e.g., neuroticism

predicts sleep cross-culturally: Kim et al., 2014). Additionally, because sleep data were only available for the second and third waves of MIDUS, we did not have the three data points required to test bidirectional effects between personality and sleep. However, testing these effects remains important: neither personality traits nor sleep are static variables (e.g., Ohayon, Carskadon, Guilleminault, & Vitiello, 2004; Roberts, Walton, & Viechtbauer, 2006). Because sleep data were not collected at the first wave of MIDUS, we were also unable to test whether baseline sleep better accounted for differences in mortality risk above and beyond personality traits. Relatedly, we were unable to control for sleep disorders in our analyses as MIDUS does not include data on whether participants were diagnosed with, or treated for, sleep disorders.

Additionally, because our study was the first to test whether sleep mediated the personality-mortality effect and investigations of the personality-sleep association are sparse, our analyses were primarily exploratory. Thus, despite conducting many analyses, we refrained from using a more stringent alpha level. We should also note that the low internal consistency of the conscientiousness scale may have limited our ability to detect effects. Similarly, because participants excluded from our sample due to missing data were more likely to be higher on agreeableness and daytime dysfunction, our indirect effects for agreeableness may have been underestimated.

Another limitation included measuring personality and sleep via self-report, potentially affecting our results due to common method variance and social desirability bias. However, our outcome variable was clearly objectively measurable: death. Moreover, self-reported personality has shown substantial overlap with informant-reported personality (e.g., McCrae & Weiss, 2015). Although self-reported sleep tends to converge modestly with objective assessments (e.g., Lauderdale, Knutson, Yan, Liu, & Rathouz, 2008), both predict important outcomes (e.g.,

diabetes: Vgontzas et al., 2009; mortality: Cappuccio et al., 2009; Kripke, Langer, Elliot, Klauber, & Rex, 2011). Thus, replicating our procedure using multimethod assessments of personality (e.g., informant-report; interview; ecological momentary assessment) and sleep (e.g., actigraphy; polysomnography; daily diary) remains important as it may allow for unique variance in mortality risk to be predicted (Vazire, 2006). Lastly, it remains unclear whether participants reported their sleep durations based on the amount of time spent in bed vs. time sleeping. Future investigations should disentangle whether time spent in bed vs. sleeping contributes to mortality risk.

In sum, we extended the personality-mortality literature by testing whether sleep accounted for this effect. In the process, we advanced the use of proportional hazards in an *SEM* framework within the personality-health literature. Our results also have important applications for personality-based health interventions. Overall, our findings suggest that short and long sleep duration and daytime dysfunction may be important pathways linking aspects of personality to reduced life expectancy.

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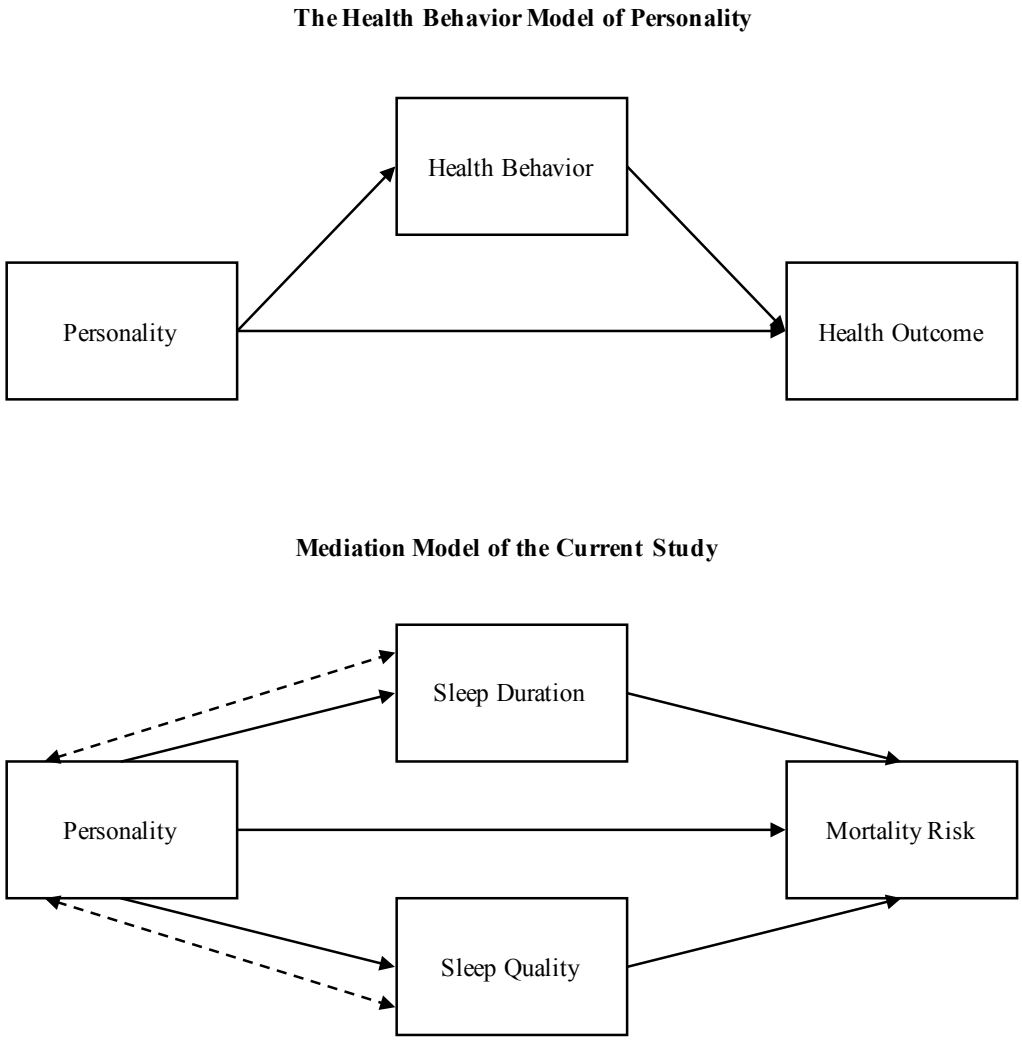

Figure 1.

In the *Health Behavior Model of Personality*, personality influences health behaviors, which, in turn, affects health outcomes. In the *Mediation Mode of the Current Study*, we examined whether personality traits predicted mortality risk through sleep duration and sleep quality: solid lines denote actual tests performed in this study, while dotted lines denote associations not tested due to methodological limitations.

Table 1

Trait and Facet Structure of the Big Five Traits

Trait	Facet
Neuroticism	Anxiety
	Angry Hostility
	Depression
	Self-Consciousness
	Impulsiveness
	Vulnerability
Extraversion	Warmth
	Gregariousness
	Assertiveness
	Activity
	Excitement-Seeking
	Positive Emotions
Openness	Fantasy
	Aesthetic
	Feelings
	Actions
	Ideas
	Values
Agreeableness	Trust
	Straightforwardness
	Altruism
	Compliance
	Modesty
	Tender-Mindedness
Conscientiousness	Competence
	Order
	Dutifulness
	Achievement Striving
	Self-Discipline
	Deliberation

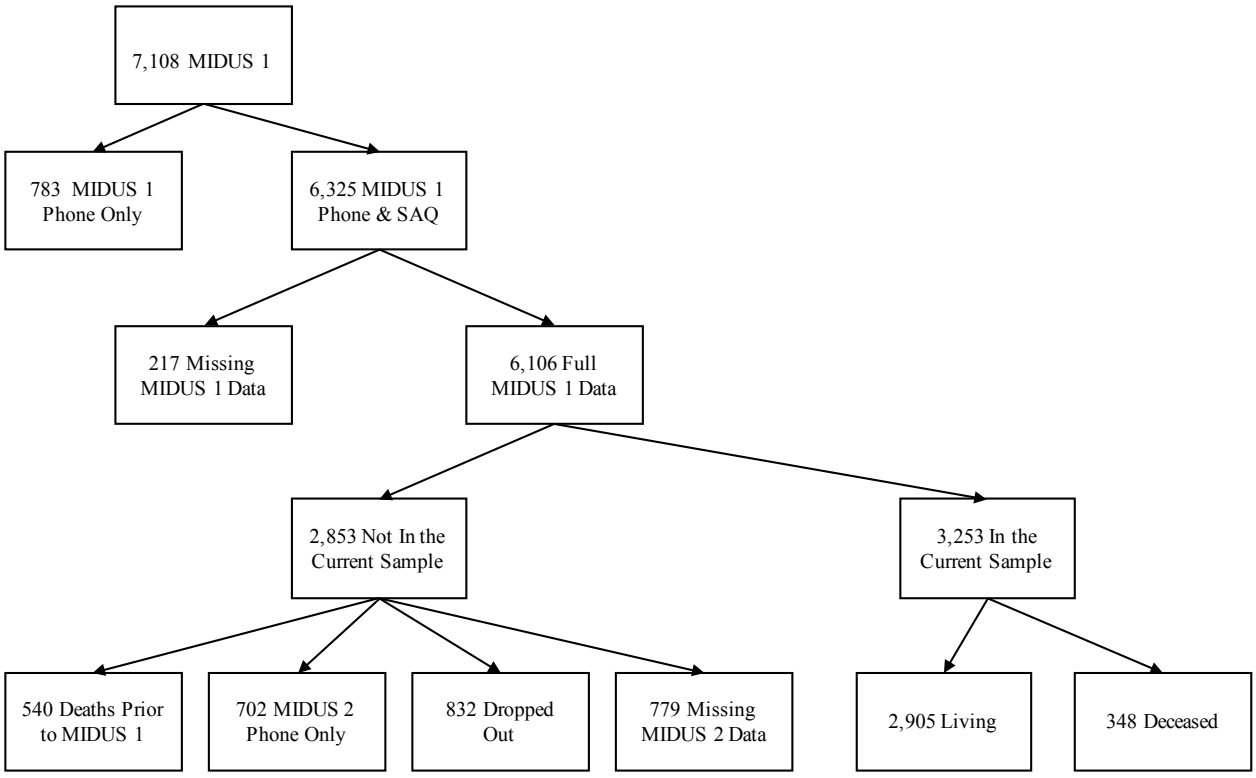

Figure 2.

Attrition and Mortality Diagram.

Table 2

Descriptive Statistics

Variables	Deceased	Alive	Full Sample (N = 3,797)			
	Mean (*SD*) or %	Mean (*SD*) or %	Mean (*SD*) or %	Range	Skew	Kurtosis
Age	59.95	45.49 (11.75)	47.03 (12.39)	20-75	0.19	-0.85
Education	6.44	7.29 (2.45)	7.20 (2.46)	1-12	0.19	-0.87
Health	3.30	3.69 (0.90)	3.65 (0.92)	1-5	-0.33	-0.21
Gender						
Male	44.25%	55.11%	53.95%			
Female	55.75%	44.89%	46.05%			
Race						
Caucasian	95.69%	94.39%	94.53%			
Other	4.31%	5.61%	5.47%			
Relationship Status						
Partnered	69.54%	76.80%	76.02%			
Not partnered	30.46%	23.20%	23.98%			
Living with child						
No child	98.28%	96.21%	96.43%			
Has child	1.72%	3.79%	3.57%			
Shiftwork	7.63 (2.18)	6.05 (2.31)	6.22 (2.35)	1-9	-0.06	-1.00
Retirement Status						
Retired	70.69%	24.99%	29.88%			
Not Retired	29.31%	75.01%	70.12%			
Waist circumference	39.14 (6.50)	37.11 (5.82)	37.33 (5.93)	18-65	0.53	0.76
Agreeableness	3.47 (0.48)	3.47 (0.49)	3.47 (0.49)	1-4	-0.85	0.43
Extraversion	3.17 (0.57)	3.18 (0.55)	3.18 (0.55)	1-4	-0.40	-0.34
Neuroticism	2.16 (0.65)	2.22 (0.66)	2.21 (0.66)	1-4	0.66	0.43
Conscientiousness	3.40 (0.45)	3.46 (0.43)	3.45 (0.43)	1-4	-0.74	0.20
Openness	3.01 (0.52)	3.01 (0.51)	3.01 (0.51)	1-4	-0.24	-0.28
Duration	430.79 (86.64)	429.45 (63.78)	429.59 (66.59)	150-600	-0.59	1.08
Sleep Quality	2.62 (1.02)	2.49 (0.86)	2.50 (0.88)	1-5	0.60	0.10
Daytime Dysfunction	2.62 (1.30)	2.53 (1.10)	2.54 (1.13)	1-5	1.13	-0.42
Sleep Problems	2.62 (2.62)	2.47 (0.93)	2.49 (0.94)	1-5	0.58	0.89

Table 3
Bivariate Correlations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. Age	-																		
2. Edu	-.11***	-																	
3. Health	-.10***	.22***	-																
4. Gender	.03	.12***	.04*	-															
5. Race	-.07***	-.03	-.06***	-.05**	-														
6. Partner	-.03	.04*	-.07***	-.10***	.10***	-													
7. Child	-.21***	.04*	.01	.03	.03	.06**	-												
8. Shift	-.44***	.21***	.15***	.13***	.01	.00	.05**	-											
9. Retire	.68***	-.08***	-.12***	.04*	-.04*	.00	-.11	-.54*	-										
10. Waist	.10***	-.11***	-.22***	.34***	.04*	-.02	-.03	-.03	.09****	-									
11. Agree	.09***	-.08***	.03*	-.27***	.04*	.02	-.04*	-.10***	.07***	-.06***	-								
12. Extra	.02	-.04*	.16***	-.06***	.03	-.02	-.01	-.01	.01	-.06***	.52***	-							
13. Neuro	-.15***	-.10***	-.20***	-.11***	.00	.05**	.01	.01	-.09***	.01	-.03	-.16***	-						
14. Cons	.02	.10***	.21***	-.12***	.00	-.04*	-.04*	.01	.02	-.15***	.28***	.27***	-.18***	-					
15. Open	-.02	.20***	.14***	.07***	.05**	.07***	.00	.06***	.00	-.05	.34**	.49***	-.17***	.27***					
16. Durat	.01	.07***	.06***	-.03	-.06***	-.02	-.02	.01	.03	-.05**	-.06**	-.01	-.06**	.02	-.03				
17. Quality	.00	-.10***	-.21***	-.15***	.01	.03	.00	-.10***	.02	.06***	.05**	-.08***	.28***	-.08***	-.09***	-.35***			
18. Dysf	-.15***	-.08***	-.22***	-.11***	.01	.07***	.04*	.02	-.10***	.08***	.02	-.11***	.28***	-.11***	-.11***	-.22***	.71***		
19. Prob	-.15***	-.08***	-.22***	-.11***	.01	.07	.04	.02***	-.10***	.08*	.02***	-.11***	.28***	-.11***	-.11***	-.22***	.71***	.48***	

Note. *** $p < .001$. ** $p < .01$. * $p < .05$. Edu = Education. Health = Self-Rated Health. Partner = Married/Living with a Partner. Child = Living with a child aged two years or younger. Retire = Retirement Status. Shift = Shiftwork. Waist = Waist Circumference. Agree = Agreeableness. Extra = Extraversion. Neuro = Neuroticism. Cons = Conscientiousness. Open = Openness. Durat = Duration. Quality = Full Sleep Quality Measure. Dysf = Daytime Dysfunction. Prob = 3-item Sleep Problems.

Table 4

Sleep Duration Predicting Mortality

Predictors	Model 1	Model 2	Model 3
	Hazard ration [95% CI]	Hazard ration [95% CI]	Hazard ration [95% CI]
Age	3.01 [2.54, 3.56]***	2.97 [2.52, 3.51]***	2.97 [2.52, 3.51]***
Race	0.84 [0.50, 1.43]	0.81 [0.48, 1.37]	0.81 [0.48, 1.37]
Gender	1.41 [1.11, 1.80]**	1.42 [1.11, 1.81]**	1.42 [1.11, 1.81]**
Education	0.81 [0.72, 0.91]***	0.81 [0.73, 0.91]***	0.81 [0.72, 0.91]***
Married/partnered	1.55 [1.23, 1.97]***	1.47 [1.16, 1.87]**	1.48 [1.16, 1.88]**
Self-rated health	0.80 [0.71, 0.89]***	0.81 [0.73, 0.91]***	0.81 [0.73, 0.91]***
Conscientiousness	0.93 [0.83, 1.04]	0.93 [0.83, 1.05]	0.93 [0.83, 1.04]
Agreeableness	0.93 [0.81, 1.07]	0.93 [0.81, 1.07]	0.93 [0.81, 1.07]
Neuroticism	1.03 [0.92, 1.16]	1.02 [0.91, 1.14]	1.02 [0.91, 1.14]
Openness	1.18 [1.04, 1.35]*	1.18 [1.03, 1.35]*	1.18 [1.03, 1.35]*
Extraversion	0.95 [0.83, 1.10]	0.95 [0.83, 1.10]	0.95 [0.82, 1.10]
Retirement status	1.52 [1.10, 2.12]*	1.55 [1.12, 2.14]*	1.55 [1.12, 2.14]*
Shiftwork	0.96 [0.83, 1.13]	0.96 [0.83, 1.13]	0.94 [0.80, 1.10]
Living with a child	1.66 [0.73, 3.78]	1.64 [0.72, 3.72]	1.64 [0.72, 3.73]
Waist circumference	1.20 [1.06, 1.35]**	1.18 [1.05, 1.33]**	1.18 [1.05, 1.33]**
Linear sleep duration	1.04 [0.94, 1.14]	1.10 [1.01, 1.20]*	1.12 [0.97, 1.29]
Quadratic sleep duration		1.12 [1.07, 1.17]***	1.12 [1.06, 1.18]***
Cubic sleep duration			1.00 [0.98, 1.02]
AIC	5075.27	5056.84	5058.77
SBC	5136.91	5122.32	5128.11

Note. AIC = Akaike Information Criterion. SBC = Schwarz Bayesian (Information) Criterion. CI = Confidence Interval. *$p < .05$. **$p < .01$. ***$p < .001$.

Table 5

Sleep Quality Predicting Mortality

Predictors	Model 1	Model 2	Model 3	Model 4
	Hazard ratio [95% CI]	Hazard ratio [95% CI]	Hazard ratio [95% CI]	Hazard ratio [95% CI]
Age	2.98 [2.52, 3.53]***	2.99 [2.52, 3.54]***	3.04 [2.57, 3.60]***	3.07 [2.59, 3.64]***
Race	0.82 [0.49, 1.39]	0.83 [0.49, 1.40]	0.83 [0.49, 1.40]	0.83 [0.49, 1.41]
Gender	1.44 [1.12, 1.84]**	1.42 [1.11, 1.82]**	1.45 [1.13, 1.85]**	1.44 [1.13, 1.84]**
Education	0.81 [0.73, 0.91]***	0.81 [0.72, 0.91]***	0.82 [0.73, 0.92]***	0.82 [0.73, 0.92]***
Married/Partnered	1.55 [1.22, 1.96]***	1.55 [1.22, 1.97]***	1.52 [1.20, 1.92]***	1.50 [1.19, 1.91]***
Self-rated health	0.81 [0.72, 0.90]***	0.80 [0.72, 0.90]***	0.82 [0.73, 0.92]***	0.82 [0.73, 0.92]***
Conscientiousness	0.93 {0.83, 1.04]	0.93 {0.83, 1.04]	0.93 {0.83, 1.04]	0.93 {0.83, 1.04]
Agreeableness	0.93 [0.81, 1.07]	0.93 [0.81, 1.07]	0.92 [0.80, 1.05]	0.91 [0.80, 1.05]
Neuroticism	1.01 [0.89, 1.13]	1.02 [0.91, 1.15]	0.99 [0.88, 1.11]	1.00 [0.88, 1.12]
Openness	1.19 [1.04, 1.35]*	1.18 [1.04, 1.35]*	1.19 [1.05, 1.36]**	1.19 [1.05, 1.36]**
Extraversion	0.96 [0.83, 1.11]	0.96 [0.83, 1.10]	0.97 [0.84, 1.12]	0.97 [0.84, 1.12]
Retirement status	1.56 [1.12, 2.17]**	1.54 [1.11, 2.14]**	1.57 [1.13, 2.18]*	1.56 [1.12, 2.16]**
Shiftwork	0.96 [0.82, 1.12]	0.96 [0.82, 1.12]	0.96 [0.82, 1.12]	0.96 [0.82, 1.13]
Living with a child	1.64 [0.72, 3.74]	1.66 [0.73, 3.78]	1.57 [0.69, 3.58]	1.57 [0.69, 3.58]
Waist circumference	1.19 [1.06, 1.34]**	1.20 [1.06, 1.35]**	1.17 [1.04, 1.32]**	1.17 [1.04, 1.32]*
Sleep Quality	1.09 [0.98, 1.21]			
Sleep Problems		1.04 [0.93, 1.15]		0.94 [0.84, 1.06]
Daytime Dysfunction			1.20 [1.08, 1.34]**	1.23 [1.09, 1.40]***
AIC	5073.46	5075.44	5065.27	5066.30
SBC	5135.10	5137.07	5126.90	5131.79

Note. AIC = Akaike Information Criterion. SBC = Schwarz Bayesian Criterion. CI = Confidence Interval. *$p < .05$. **$p < .01$. ***$p < .001$.

Table 6

The Big Five, Quadratic Sleep, and Daytime Dysfunction Predicting Mortality

Predictors	Model 1	Model 2	Model 3	Model 4
	Hazard ratio [95% CI]	Hazard ratio [95% CI]	Hazard ratio [95% CI]	Hazard ratio [95% CI]
Age	3.29 [2.90, 3.74]***	3.34 [2.94, 3.80]***	3.00 [2.54, 3.56]***	3.03 [2.57, 3.58]***
Race	0.88 [0.52, 1.49]	0.88 [0.52, 1.49]	0.83 [0.49, 1.40]	0.82 [0.48, 1.39]
Gender	1.73 [1.39, 2.15]***	1.66 [1.32, 2.08]***	1.42 [1.11, 1.81]**	1.46 [1.14, 1.87]**
Education	0.84 [0.76, 0.94]**	0.81 [0.72, 0.91]**	0.81 [0.72, 0.91]***	0.82 [0.73, 0.91]***
Married/partnered	1.57 [1.24, 1.99]***	1.51 [1.20, 1.92]***	1.55 [1.22, 1.96]***	1.45 [1.15, 1.84]**
Self-rated health	0.76 [0.68, 0.84]***	0.77 [0.69, 0.86]***	0.80 [0.71, 0.89]***	0.84 [0.75, 0.94]**
Conscientiousness		0.93 [0.83, 1.04]	0.93 [0.83, 1.04]	0.93 [0.83, 1.05]
Agreeableness		0.95 [0.83, 1.09]	0.92 [0.80, 1.07]	0.92 [0.80, 1.05]
Neuroticism		1.03 [0.92, 1.15]	1.03 [0.92, 1.16]	0.98 [0.87, 1.10]
Openness		1.18 [1.03, 1.34]*	1.19 [1.04, 1.35]**	1.19 [1.04, 1.36]**
Extraversion		0.95 [0.83, 1.10]	0.95 [0.83, 1.10]	0.96 [0.80, 1.09]
Retirement status			1.53 [1.10, 2.13]*	1.58 [1.14, 2.18]**
Shiftwork			0.96 [0.83, 1.13]	0.93 [0.80, 1.09]
Living with a child			1.67 [0.73, 3.79]	1.57 [0.69, 3.57]
Waist circumference			1.20 [1.06, 1.35]**	1.16 [1.03, 1.30]*
Linear Sleep				1.13 [1.03, 1.23]**
Quadratic Sleep				1.11 [1.06, 1.16]***
Daytime Dysfunction				1.19 [1.07, 1.33]**
AIC	5081.31	5083.58	5073.85	5049.31
SBC	5104.42	5125.96	5131.63	5118.65

Note. AIC = Akaike Information Criterion. SBC = Schwarz Bayesian (Information) Criterion. CI = Confidence Interveal. *$p < .05$. **$p < .01$. ***$p < .001$.

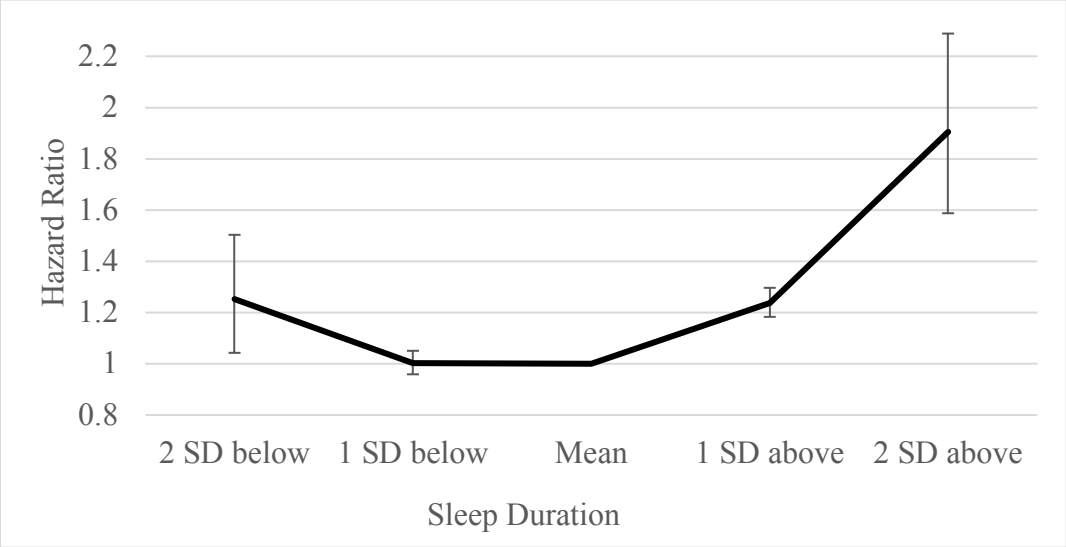

Figure 3.

The curvilinear effect of sleep duration on mortality risk.

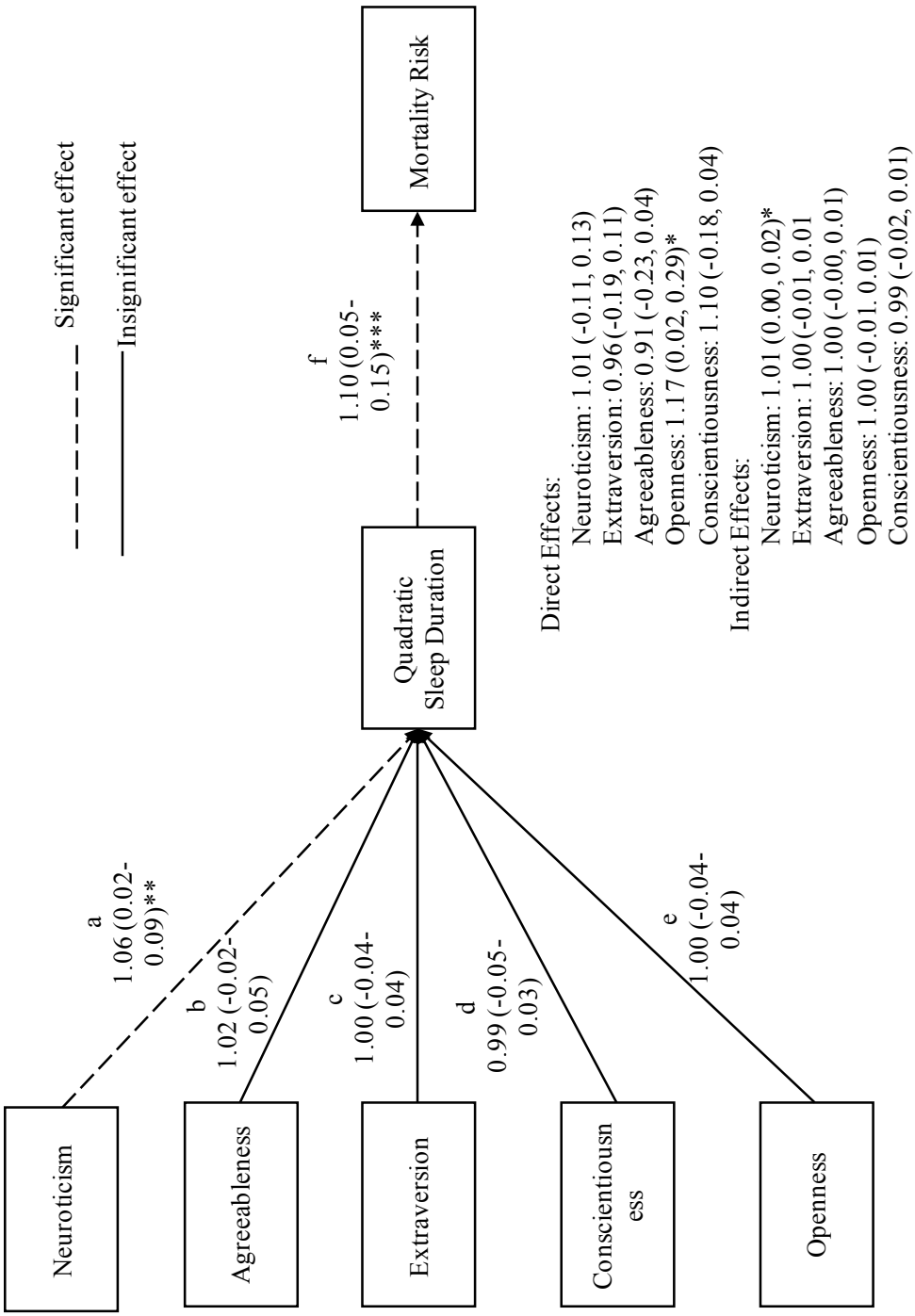

Figure 3.
Fully adjusted path model controlling for age, race, relationship status, education, self-rated health, retirement status, living with a child under the age of two years, shiftwork, and waist circumference. * $p < .05$. ** $p < .01$. *** $p < .001$.

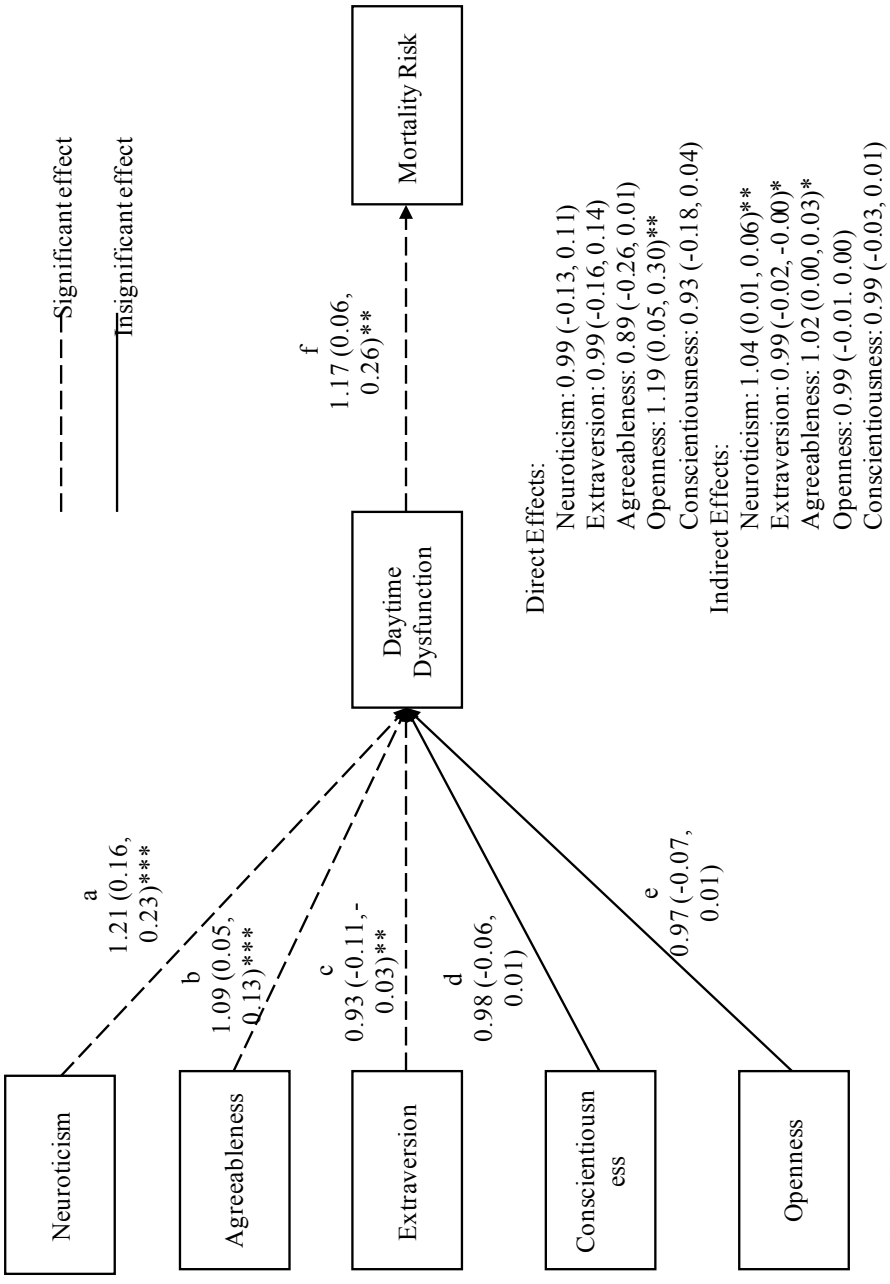

Figure 4.
Fully adjusted path model controlling for age, race, relationship status, education, self-rated health, retirement status, living with a child under the age of two years, shiftwork, and waist circumference. * $p < .05$. ** $p < .01$. *** $p < .001$.

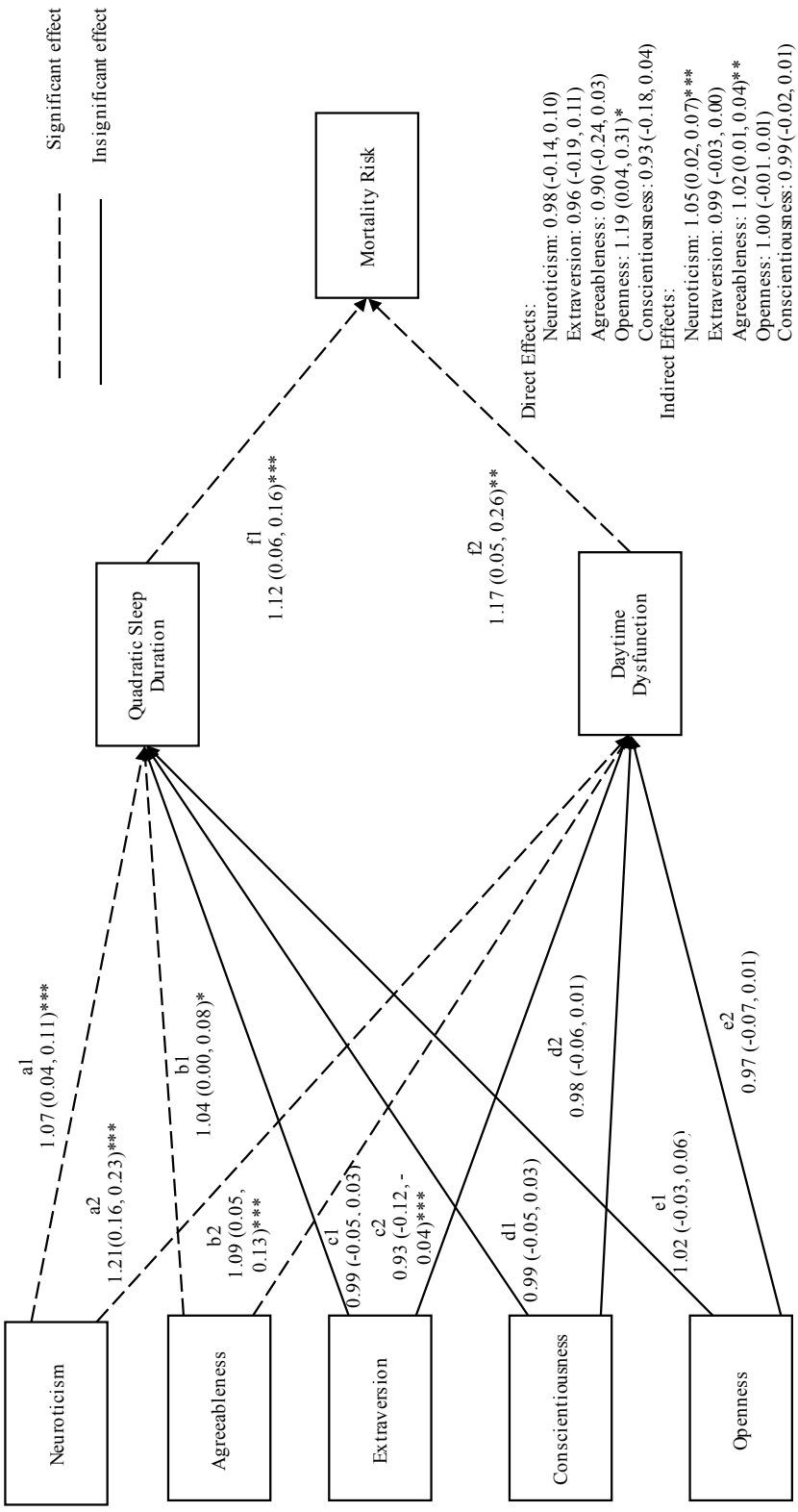

Figure 5.
Fully adjusted path model controlling for age, race, relationship status, education, self-rated health, retirement status, living with a child under the age of two years, shiftwork, and waist circumference. * $p < .05$. ** $p < .01$. *** $p < .001$.

Table 7

Indirect Effects for Full Sample and for Sample Stratified by Gender and BMI

		N	E	A	O	C	N	E	A	O	C	N	E	A	O	C
		Daytime Dysfunction					Quadratic Sleep Duration					Joint Indirect Effect				
Full Sample		+	-	+			+					+	+			
Gender	Male	+	-	+								+	-	+		
	Female						+									
BMI	Non-Obese											+				
	Obese	+		+								+		+		

Note. N = Neuroticism. E = Extraversion. A = Agreeableness. O = Openness. C = Conscientiousness. BMI = Body Mass Index.

Appendix

1. What is the month, day, and year of your birth? _____ / _____ / _____
Month /Day /Year

2. The next questions are for classification purposes. What is the highest grade of school or year of college you completed?

1. No School/Some Grade School (1-6)
2. Eighth Grade/Junior High School (7-8)
3. Some High School (9-12 No Diploma/No Ged)
4. GED
5. Graduated from High School
6. 1 To 2 Years of College, No Degree Yet
7. 3 or More Years of College, No Degree Yet
8. Graduated from a Two-Year College or Vocational School, or Associate's Degree
9. Graduated from a Four-or Five-Year College, or Bachelor's Degree
10. Some Graduate School
11. Master's Degree
12. Ph.D., ED.D., MD, DDS, LLB, LLD, JD, or other professional degree

3. Are you married or living with someone?
   1. Yes
   2. No

4. Sex:
   1. male
   2. female

5. What race do you consider yourself to be? (Please circle only one response.)

1. White
2. Black and/or African American
3. Native American or Aleutian Islander/Eskimo
4. Asian or Pacific Islander

6. In general, would you say your physical health is excellent, very good, good, fair, or poor?
   1 = Poor
   2 = Fair
   3 = Good
   4 = Very good
   5 = Excellent

7. What about your current employment situation -- are you working now for pay, self-employed, looking for work, temporarily laid off, retired, a homemaker, a full-time or part-time student, or something else?

1. Working Now
2. Self-Employed
3. Looking for Work; Unemployed
4. Temporarily Laid Off
5. Retired
6. Homemaker
7. Full-Time Student
8. Part-Time Student
9. Maternity or Sick Leave (Volunteered)
10. Permanently Disabled (Volunteered)
11. Other_____(Specify)

8. Now think about your current job(s). In an average week, how often do you work during the day, in the evening, at night (including being away overnight for work-related travel), or on the weekend? Answer these questions even if you are temporarily on leave or laid off from your main job and think about that job when answering the questions.

In an average week, how often do you work…	4 or more times/week	2 to 3 times/week	Once a week	1 to 3 times/month	Less than once a month or never
Nights, any time between 9:30pm and 4:30 am, or overnight?	1	2	3	4	5

9. How many children do you have? Include biological, adopted, step and foster children living with you or elsewhere. Also include all living children you have [given birth to/fathered]. (Please include only living children).

10. What is your child's age?

11. Does [name] currently live in your household - CHILD/HH MEMBER #1?

1. Yes
2. No

12. What is your waist size--that is, how many inches around is your waist? Please measure at the level of your navel.

Midlife Development Personality Inventory

1. Please indicate how well each of the following describes you.

	A Lot	Some	A Little	Not at All
a. Outgoing	1	2	3	4
b. Helpful	1	2	3	4
c. Moody	1	2	3	4
d. Organized	1	2	3	4
e. Self-Confident	1	2	3	4
f. Friendly	1	2	3	4
g. Warm	1	2	3	4
h. Worrying	1	2	3	4
i. Responsible	1	2	3	4
j. Forceful	1	2	3	4
k. Lively	1	2	3	4
l. Caring	1	2	3	4
m. Nervous	1	2	3	4
n. Creative	1	2	3	4
o. Assertive	1	2	3	4
p. Hardworking	1	2	3	4
q. Imaginative	1	2	3	4
r. Softhearted	1	2	3	4
s. Calm	1	2	3	4
t. Outspoken	1	2	3	4
u. Intelligent	1	2	3	4
v. Curious	1	2	3	4
w. Active	1	2	3	4
x. Careless	1	2	3	4
y. Broad-minded	1	2	3	4
z. Sympathetic	1	2	3	4
aa. Talkative	1	2	3	4
bb. Sophisticated	1	2	3	4
cc. Adventurous	1	2	3	4
dd. Dominant	1	2	3	4

MIDUS 2 Self-Administered Questionnaire Sleep Questions

1. How much sleep do you usually get at night (or in your main sleep period) on weekdays or workdays?
_____Hours_____Minutes
2. How much sleep do you get at night (or in your main sleep period) on weekends or your non-workdays?
_____Hours_____Minutes

3. Please indicate how often you experience each of the following:

(Circle the appropriate number for each item.)

	Never (0 times)	Rarely (Once a month or less)	Sometimes (2-4 times per month)	Often (2-3 times per week)	Almost Always (4 or more times per week)
a. Have trouble falling asleep	1	2	3	4	5
b. Wake up during the night and have difficulty going back to sleep	1	2	3	4	5
c. Wake up too early in the morning and be unable to get back to sleep	1	2	3	4	5
d. Feel unrested during the day, no matter how many hours of sleep you had	1	2	3	4	5